

WHAT IS CLAIMED IS:

1. An apparatus to manipulate an object comprising: a pair of actuated compliant beams, mounted substantially perpendicular to each other, which can grip and manipulate the object.

2. The apparatus of claim 1 wherein each compliant beam includes a piezoelectric actuator.

3. The apparatus of claim 2 wherein one end of the piezoelectric actuator is attached to a proximal end of a base member.

4. The apparatus of claim 3 wherein a tip member is attached to a distal end of the base member.

5. The apparatus of claim 4 wherein the tip member has an inclined face configured to engage the object to be manipulated.

6. The apparatus of claim 5 wherein the face of the tip member is inclined at angle of approximately 45 degrees.

7. The apparatus of claim 4 wherein a strain gauge is located at a face and back of each of the base member and the tip member.

8. The apparatus of claim 3 wherein the piezoelectric actuator drives a distal end of the base member.

9. The apparatus of claim 8 wherein the piezoelectric actuator drives the distal end of the base member through a point contact.

10. The apparatus of claim 2 further including a tip member joined to one end of the piezoelectric actuator.

11. The apparatus of claim 1 wherein each compliant beam includes an actuator selected from the group consisting of a thermal actuator, a motor-driven beam actuator, a polymer/thermal actuator, and a flexible circuit actuator.

12. The actuator of claim 1 further including at least one strain gauge to measure a deflection of a beam or a force applied by a beam.

13. The apparatus of claim 1 wherein one of the beams can only be driven along a first axis, while the other one of the beams can only be driven along a second axis that is perpendicular to the first axis.

14. The apparatus of claim 13 wherein each beam is fixed to a surface.

15. An apparatus to manipulate an object comprising:
a first arm that is actuated only along a first axis;
a second arm that is actuated only along a second axis that is substantially perpendicular to the first axis; and
the first and second arms defining a space therebetween in which an object can be positioned such that the first and second arms can grip and manipulate the object.

16. A system to manipulate an object comprising:
a first arm that is actuated only along a first axis;
a second arm that is actuated only along a second axis that is substantially perpendicular to the first axis; and
the first and second arms defining a space therebetween in which an object can be positioned such that the first and second arms can grip and manipulate the object; and
an XYZ stage on which the object can be positioned.

17. A method of manipulating an object comprising:
grasping one side of the object with a first arm that is actuated only along a first axis;
grasping another side of the object with a second arm that is actuated only along a second axis that is substantially perpendicular to the first axis; and
actuating at least one of the first and second arms to manipulate the object.

18. The method of claim 17 wherein the first and second arms are actuated to roll the object.

19. The method of claim 17 wherein the first and second arms are actuated to pick and place the object.

20. The method of claim 17 wherein the first and second arms are actuated to reorient the object perpendicular to a grasping wall.

21. The method of claim 17 wherein the first and second arms are actuated to align the object along a wall.

22. A method of manipulating a submillimeter-sized object comprising:

gripping one side of the object with a first actuated compliant beam;

gripping another side of the object with a second actuated compliant beam that is mounted substantially perpendicular to the first beam; and

operating the first and second beams to manipulate the object.

23. A method of manipulating an object comprising:

grasping one side of the object with a first beam that is actuated only along a first axis;

grasping another side of the object with a second beam that is actuated only along a second axis that is perpendicular to the first axis;

positioning the object in a groove in a wall as the object is grasped by the first and second beams;

controlling the position of the wall and the first beam such that the wall and the first beam grasp the object, while the second beam is transferred to another side of the object;

controlling the position of the wall and the second beam such that the wall and the second beam grasp the object, while the first beam is transferred to yet another side of the object;

moving the wall away from the object; and

operating the first and second beams to rotate the object 90 degrees.

24. The method of claim 23 wherein the steps thereof are repeated to rotate the object 360° degrees.